ZOOLOGICA

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1.

The Breeding Behavior of the Common Shiner, *Notropis cornutus* (Mitchill).

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(Plates I-IV; Text-figure 1).

Although several authors have written concerning the habits of the common shiner, *Notropis cornutus* (Mitchill), there is little detailed information available on the breeding behavior of this widely distributed cyprinid. The more pertinent papers giving data on spawning are those by Adams & Hankinson (1928), Greeley (1927 and 1929) and Hankinson (1932). The author has made an intensive study of the breeding habits of the common shiner, *Notropis cornutus cornutus*, during the past spring (1939) in the region about Ithaca, New York, and these data, together with observations made elsewhere mostly during the previous four years, are presented here. The breeding act has been observed many times at various places and under different conditions. However, the details were obscured, as they are in many fishes, because of the rapidity of consumation until photographs were taken under nearly ideal conditions in nature (see Plates I-IV). The method used in securing the photographs was similar to that used by some ornithologists. A nest of common shiners was located at a spot where the water was shallow and clear. If the shiners were at a high pitch in their spawning activity they would return after a period ranging from one-half to several hours and carry on normally with the camera mounted on a tripod and operated by an observer only 4 to 5 feet away. By utilizing exposures of 1/100 of a second or less most action could be stopped and the spawning process pictured. This method will probably be helpful in studying the habits of other nest building species among our fresh water fishes.

MIGRATION.

An inshore migration in lakes and, at least in some localities, an upstream movement is made by the common shiner. At the south end of Cayuga Lake, near Ithaca, New York, large schools are found moving toward

shore during the first two weeks in May when the water has reached a temperature of 55° to 60° F. Their coming is eagerly awaited by bait dealers since, at this time, the common shiner is in demand as bait for the pike, *Esox lucius*. Nurnberger (1931, p. 215) has noted the presence of large schools of the common shiner appearing along the shore of Big Sandy Lake, Minnesota, on June 1, 1928, when the water temperature was 68° F. In the absence of actual reported observations of spawning in ponds and lakes it is assumed that the common shiner resorts to the gravel riffles of tributary streams, but Hubbs & Cooper (1936, p. 65) have pertinently stated that "its abundance in some of the inland lakes (Michigan) suggests that it may also spawn successfully over the gravel shoals of these lakes."

In streams there appears to be at least a slight upstream migration from the deeper pools where the adults have wintered. On May 8, 1939, adult common shiners were found moving upstream into the trap of a weir placed across Grout Brook, the inlet of Skaneateles Lake, Cortland County, New York. Constant surveillance of the waters below the weir had failed to note any shiners before this date. The nearest satisfactory wintering place was 300 or more yards away and it is not at all improbable that they wintered in the lake 600 yards distant. Just how far individual shiners may migrate is, in the absence of tagging experiments, unknown.

Sexual Dimorphism.

Sexual dimorphism is pronounced in the common shiner, as in most other nest building or territory guarding cyprinids, as *Semotilus, Campostoma* and *Nocomis*. Breeding males of the common shiner attain a larger size, have well developed pearl organs or breeding tubercles and are more highly colored than females. It is obvious that the largest females in a stream exceed in size the smallest breeding males (Text-figure 1). Nevertheless the difference in size is one of the best characters for distinguishing the sexes at a given nest and in many instances of spawning I have yet to see a male spawn with a larger female. It is difficult to generalize regarding the actual sex ratio but with adult shiners on the spawning ground invariably there are more females than males. The maximum size for male common shiners is about 8 inches in total length. A male *Notropis cornutus chrysocephalus* in breeding color is figured in Forbes & Richardson (1920: opposite page 147) and a male *Notropis cornutus frontalis* in Greeley (1927: plate number 5).

The following color notes were made one hour after preservation in 10% formalin, from specimens of *Notropis cornutus cornutus* taken from over a nest in Salmon Creek at Ludlowville, New York, on June 6, 1939. The sides of the breeding males become suffused with red, the amount varying considerably with the individual. The posterior border of all fins tends to have a red band which in turn is edged by a much narrower clear area. There is a pronounced tendency for the pectoral and ventral fins to become suffused throughout with red except for a light posterior border and a milky white anterior border. The rays of the dorsal, caudal and pectoral fins tend to become dusky just anterior to the red band while the base of the anal fin usually remains milky white. The base of the ventral fins shows a slight tendency to become dark in some individuals. The branchiostegals are red and the lower part of the cheek and opercles are at times a dull red. The upper part of the opercles and cheek are a slate blue as well as a narrow band immediately behind the opercle. There is a longitudinal mid-dorsal streak and a streak on each side of the back which vary from a silver to a greenish color but at all times are highlights on a dark background which make excellent field recognition characters (see Plate II).

Breeding females are dusky above and silvery along the sides. In a few cases a slight amount of red has been seen, especially at the posterior border of the caudal and anal fins. The rays of the dorsal, pectoral and caudal fins

tend to become dusky while the ventral and anal fins are usually white. While females have a faint longitudinal streak down the mid-line of the back and one along each side of the back they are not as pronounced as in the males. The swollen abdominal region of the ripe or near ripe female is also a helpful field character.

The males begin to show color about a month before spawning, a subdued red tint appearing first on the lower fins. The red which is to be seen along the sides in the ripe males develops last and appears only a few days before spawning takes place. After breeding the color fades quickly and is usually gone in two weeks, the red on the sides being the first to go. However, an occasional male is taken even in late summer with a slight amount of color in the fins.

The breeding male has well developed pearl organs scattered on the back in front of the dorsal fin, on the nape, on the top of head and on the snout; a few under the anterior part of the eye, in the region of the premaxillaries and maxillaries and a single row along the lower jaw. The tubercles on the head are better developed than the more posterior ones. A few minute pearl organs occur on the upper sides, below and in front of the dorsal fin; on the posterior border of the opercle; on a few of the anterior scales just dorsad of the base of the pectoral and on the belly between the pectoral and ventral fins. An irregular row of fairly large pearl organs is to be seen on the anterior edge of the first ray of the dorsal fin and smaller ones occur on the sides of the first few dorsal rays. The dorsal side of the pectoral fins are well supplied with fairly large tubercles which undoubtedly are of use in enabling the male to hold the female in spawning. Minute tubercles occur on the ventral side of the pectoral and on both sides of the ventral fins near the anterior border. A careful examination of a dozen ripe females disclosed no tubercles. However, Fowler (1912, p. 473) reports that "occasionally a tuberculate female is found."

As with the color, the tubercles of the male grow gradually, starting about a month before spawning, and are usually gone within two weeks after spawning, although the scars of the larger pearl organs may often be seen up until one month after breeding.

Functions of Breeding Tubercles.

The well developed breeding tubercles on the snout, chin, head and on the back, in front of the dorsal fin, of the males are of unquestionable value in the fighting which takes place in attempting to hold a territory and in driving away predators which attempt to eat the eggs. These tubercles are also a protection to the male in the sporadic digging activities in which they engage. Probably the only tubercles which are of value in the spawning act are those on the dorsal side of the pectoral fin which functions as a grasping organ and those on the ventral side between the pectoral and ventral fins which come in direct contact with the side of a female (Plate II).

Time of Spawning.

In Big Sandy Lake, Minnesota, Nurnberger (1931, p. 215) reports that spawning occurred in 1929 between June 24 and 29 when the water reached 66°-70° F. In Illinois, according to Forbes & Richardson (1920, p. 148) spawning occurs from May 1 to the last of June. Hubbs & Cooper (1936, p. 65) give the spawning season in Michigan as extending from the latter part of May into June and mention that "spawning probably rarely occurs at water temperatures lower than 60° to 65° F." In western Pennsylvania spawning takes place in May and June while in New York the season may extend from the last two weeks in May until the middle of July in some of the colder Adirondack streams. About Philadelphia, Pennsylvania, Fowler

(1909, p. 540) reports that the shiner spawns from late April to early summer. Tracy (1910, p. 68) gives spring and early summer as the season in Rhode Island. In the Connecticut Lakes in Maine Kendall & Goldsborough (1908, p. 31) give the breeding time as spring or early summer, depending on the temperature of the water.

The lowest water temperature at which I have actually observed shiners spawn is 64° F. but they very likely begin to spawn at a temperature of 60 F. or thereabouts. However, in certain cold streams spawning probably occurs at a slightly lower temperature. Spawning has personally been observed when the water temperature was as high as 78° F. and Greeley (1929, p. 172) saw *Notropis cornutus frontalis* spawning in Silver Creek, a tributary of Lake Erie, Chautauqua County, New York, as late as July 9 at a water temperature of 83° F. At any one locality spawning is usually over in ten days although ripe males are often seen for longer periods.

No breeding was observed taking place at night and at this time few adult fishes remain in close proximity to the nest. Most of them retire to the deeper pools nearby where they are relatively inactive. The spawning act was seen as early as 9 A.M. on May 27, 1939, in Willseyville Creek at Willseyville, Tioga County, New York. Spawning reached a high point about 12 noon and gradually tapered off after 4 P.M., none being noted later in the day than 6 P.M. Spawning had reached a peak of activity at this particular locality on May 27. Earlier and later in the season there was but little breeding activity at this place except in the afternoon.

Spawning Site.

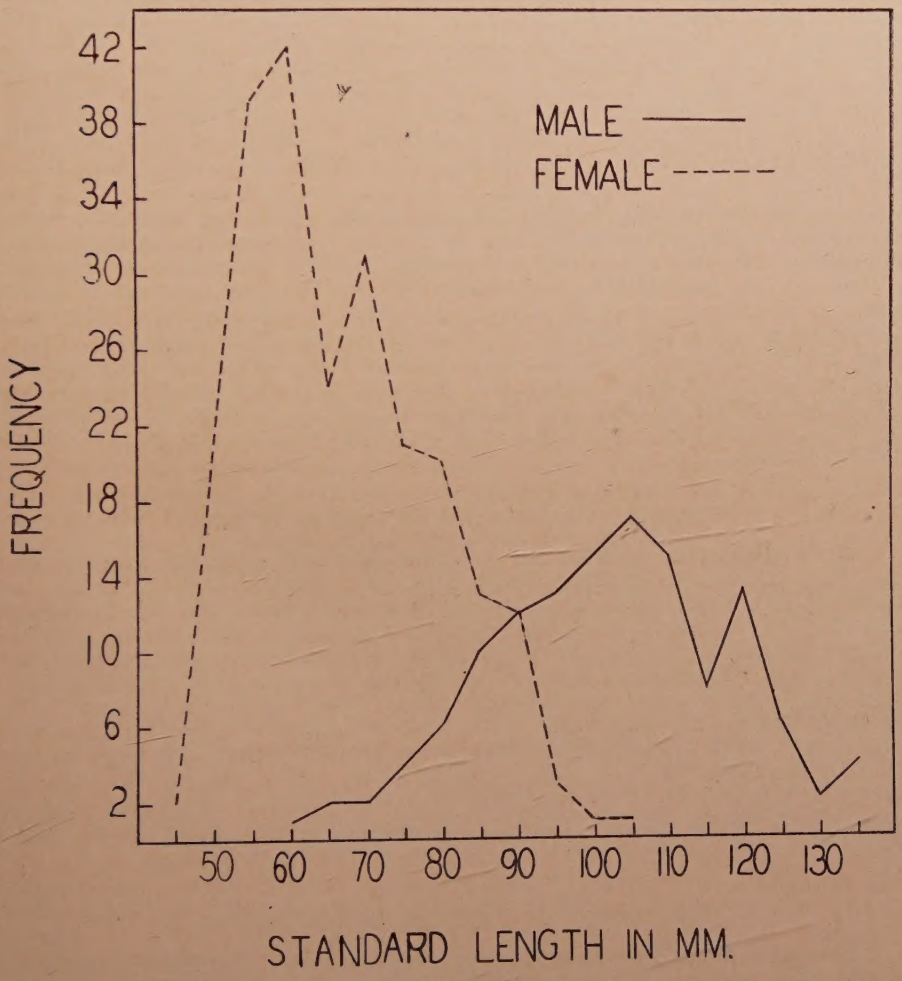
A very important factor in explaining the wide distribution and the local abundance of the common shiner is its capacity to spawn successfully in many different habitats. Shiners may (1) spawn over gravel beds in running water, (2) excavate small depressions in gravel or sand in running water or, (3) utilize the nests built by other species (Plate I), even when these nests occur in pools as is frequently the case with *Exoglossum*. They appear to prefer the nests of other species as nesting sites when they are available, although in 100 yards of Catatonk Creek, at Candor, New York, on May 31, 1939, shiners were observed utilizing all three of the above-mentioned nesting places. Their preference for *Exoglossum* nests, especially in small streams, often finds them spawning over these nests in the relatively quiet waters of shallow pools rather than using the gravel riffles which are so common nearby. The depth of the water over a spawning site is usually less than 8 inches except when nests of other fishes are used. Four large male shiners were once observed spawning over an *Exoglossum* nest situated at the edge of a deep pool in 2 feet of water.

Gravel Beds as a Nesting Site.

Shiners often utilize gravel in or at the head of riffles as a spawning site. These areas can hardly be considered nests although they can easily be distinguished by the cleared nature of the bottom. The clearing away of the silt is accomplished in two ways; first, by the constant moving of the male fish over the gravel during which the lower fins make some contact with the bottom, and, second, by the occasional sporadic digging motions practiced by the male. He inserts his head between two pebbles and, by a quick sidewise motion, dislodges one or both of them. Only rarely do they pick up small stones in their mouths.

Fowler (1909, p. 540) has observed breeding schools of several hundred brilliantly colored males packed close together over clear gravel or sandy shallows in the region about Philadelphia, Pennsylvania. Several splendid opportunities have been had recently for observing spawning (subspecies *cornutus*) over gravel in Fall Creek, Ithaca, New York, and in Salmon Creek,

at Ludlowville, New York. In western Pennsylvania *Notropis cornutus chrysocephalus* has been observed spawning over gravel in riffles. Of the above-mentioned localities when gravel is utilized many more shiners spawn together over a given area than when the nests of other species are used. At Ludlowville on June 6, 1938, from 80 to 100 males (Text-figure 1) had taken a position in a riffle over a gravel bottom where the water varied in depth from three to five inches. Under such conditions each male attempts to hold a small territory which, of course, is quite limited because of the large number of males in such a restricted area and, at most, consists of a distance of three inches or so to either side. Much fighting occurs among the males but after one retreats from the rush of another male he usually comes back to his original position and the rushes may be repeated many times between spawnings. The offensive activity of a male consists in quickly



Text-figure 1.

Frequency distributions of breeding males and females of *Notropis cornutus cornutus* taken from over one spawning area in Salmon Creek, at Ludlowville, Tompkins County, New York, on June 6 and 9, 1939. Measurements of standard length were taken on 130 males and 232 females preserved in alcohol.

circling either to right or left and attempting to strike with the tubercled snout. Few direct hits are made as opposing males are usually alert and beat a quick retreat at the moment an antagonist starts circling. The water "boils" over such groups of males as they break water with their dorsal and caudal fins during this fighting and manouvering for position. Occasionally "deferred combat" (Reighard, 1910, p. 1129) occurs as two males of nearly the same size (Plate III) tensely swim off parallel to each other, often for a distance of 3 to 5 feet. If they are of equal size they soon return to or close to their original position on the gravel. There was a tendency at times for this large breeding group to break into two, about half the males moving upstream several feet and there repeating the same combat for territory.

Approximately 150 females could be seen on the gravel below the holdings of the males. When they were ready to breed the females would come upstream and take a position over a male and spawning would take place in a manner to be described later. This large spawning group was somewhat unusual in that it was located in a shaded spot under a huge American elm tree and received no direct sun during the afternoon. In such a situation where spawning occurs over coarse gravel the eggs may be seen and recovered by picking up or scuffing the pebbles. Some of the eggs are free between pebbles, singly or in groups, while others are found adhering to the stones.

At times, especially toward the end of the spawning season, a large depression is made on the bottom by a large group of spawning males. Whether a nest-like excavation is apparent depends somewhat on the type of bottom. At Ludlowville the pebbles were fairly large, averaging about one inch in diameter with few under one-half inch in diameter. Under conditions such as this the digging activities of the males have little effect other than to give a clean look to the area. In lower Fall Creek, at Ithaca, New York, a similar breeding group will excavate a shallow depression in the bottom consisting of sand and small gravel, which is often 3 to 4 feet in diameter. Such nests are hardly distinguishable from the type which is discussed next.

Nests Excavated by the Common Shiner.

Both subspecies *cornutus* and *frontalis* have been observed digging and guarding their own circular nests, which are usually 8 to 12 inches in diameter. In most cases a pit partly or wholly excavated by *Semotilus* (Plate I) or *Campostoma* is taken over by a number of shiners, the number varying usually from 3 to 20 males although occasionally but one male occupies a nest. These nests are most often built at the head of a riffle but are also often seen in fairly fast flowing riffles. They are probably never built in quiet water. The males make the nests by digging activities in which they insert their heads between two stones and by jerking the head to the side dislodge the stones laterally. Several males will engage in this digging at one time although there are frequent interruptions as the males dash at each other, vieing for the position furthest upstream in the nest. This digging usually occurs irregularly between spawning acts.

Utilization of Nests of Other Fishes.

Several authors including Greeley (1929, p. 172), Hankinson (1920, p. 8, and 1932, p. 415), Hubbs & Cooper (1936, p. 65) and Van Duzer (1939, p. 73) have pointed out instances of the common shiner utilizing the nests of other species, such as *Nocomis micropogon, Nocomis biguttatus, Semotilus a. atromaculatus, Leucosomus corporalis, Exoglossum maxillingua* and *Campostoma anomalum.* Shiners appear to prefer the pebble nests of *Nocomis* and *Exoglossum* when available. Their second choice under most

conditions appears to be the pit and ridge nest dug by *Semotilus* and the author has observed them taking over and enlarging the circular pits excavated by male *Campostoma anomalum pullum*. The breeding pattern is the same, however, whether the nest of another species is utilized or a nest of its own is excavated.

On several occasions *Semotilus* and *Nocomis* have been working on their nests at the same time that shiners were spawning there. The male shiners seldom attacked a male *Semotilus* and the *Semotilus* in turn continued removing stones from his pit and piling them in a ridge upstream (see Reighard, 1910, p. 1125). At times he would turn on and strike with his tuberculate head a shiner that became too bold. As Hankinson (1932, p. 418) has pointed out a male *Nocomis* will frequently continue bringing stones to add to his ever-growing nest even though many shiners are present and spawning is occurring. An amazing example of the complacency of a male *Nocomis micropogon* was noted in Catatonk Creek at Candor, New York, on May 31, 1939. Twenty male and thirty female *cornutus* were swarming over a *Nocomis* nest. These were accompanied by a dozen breeding *Notropis rubellus*. A number of specimens of *Exoglossum maxillingua* and *Rhinichthys cataractae* were darting in from their position on the periphery to eat what eggs they could secure. During this great activity which made the water "boil" over the nest, the male *Nocomis* calmly added stones to his nest for a period slightly more than one hour without at any time attacking any of the breeding fishes that were so close. At the same time the male shiners carefully respected the *Nocomis*. However, female *Semotilus* or *Nocomis* seldom appear when shiners swarm the nests, and actual spawning has not been seen under these conditions.

With spawning *Exoglossum*, as Van Duzer (1939, p. 73) has pointed out, "the mating of the cut-lips was always definitely lessened and sometimes stopped by their (*cornutus*) presence and activity at the nest." It is quite probable that the male *cornutus* have learned to respect the sizeable male *Semotilus* and *Nocomis*, armed as they are with well developed pearl organs on the head, while they have become equally familiar with the abortive rushes of the non-tuberculate and usually smaller male *Exoglossum*.

An interesting side light is the considerable number of natural hybrids which occur largely as a result of this habit of spawning over the nests of other species. Two species have often been seen spawning at the same time over a *Nocomis* nest.

Hybrids of the combination *Notropis cornutus* × *Notropis rubellus* are frequently collected and both of these species have been seen spawning over a *Nocomis* nest at the same time (see Hankinson, 1932, p. 417). The hybrid *Notropis cornutus* × *Nocomis micropogon* has been recorded by Greeley (1938, p. 51). *Clinostomus elongatus* spawns over the nests of both *Notropis cornutus* and *Semotilus atromaculatus atromaculatus* and both Greene (1935, p. 89) and Greeley (1938, p. 51-52) have recorded the hybrids *Notropis cornutus* × *Clinostomus elongatus* and *Semotilus atromaculatus atromaculatus* × *Clinostomus elongatus*. Greeley (1938, p. 52) has also reported hybrids *Notropis cornutus* × *Semotilus atromaculatus atromaculatus* and *Notropis cornutus* × *Leucosomus corporalis* which likely result from *cornutus* spawning over the nests of these species. Thompson (1935, p. 492) has mentioned that in Illinois hybrids of *Notropis cornutus* are common presumably because *cornutus* spawns in the nests of other species.

Sex Recognition.

The female that successfully spawns, invariably approaches the nest from the downstream side and assumes a position dorsad and slightly downstream from the male, who faces upstream (Plate I). Should she continue upstream to a position in front of a male, as occasionally happens, she would be driven away by the rush of a male, usually the male holding the dominant

position in the nest. The male would usually dart at and cause to retreat downstream any female getting into the nest at his body level, that is, near the bottom of the nest. In case a female was chased she would beat a retreat downstream, assume a position from one to several feet below the nest and then gradually come upstream again over a male. The constant turning of his head from side to side enables him to spot any fish which comes above him. The behavior of a male when a female has assumed a position above him is evidence that he recognizes her by the position she takes. The male at this time will, while facing upstream with body nearly straight, incline his body from side to side so that his reddish sides flash alternately (Plate I). While the male may react to the mere presence of a fish body above and behind him, there is a possibility that the male is attracted by the milky white area about the slightly protruding external opening of the oviduct of the female. In the case of one ripe female, but two inches long, this white area was so pronounced it might easily be seen by an observer standing five feet away. It must surely be an attractive mark when viewed from the position of the male. A female will take a position above any male who is in or slightly below the nest. Often a small male on the outside edge of the nest (Plate II) will be successful in spawning more often than the large male dominating the nest since the latter is forced to spend a large part of his time attempting to chase away other fishes. However, one exceptionally large and vigorous male was once seen holding a *Semotilus* pit so effectively by his wild dashes at intruding male *cornutus* that he successfully spawned with a half-dozen females in about one and one-half minutes before any other males seriously challenged and finally displaced him.

There is one bit of evidence that female *cornutus* react to fish of larger size whether of the same species or not. At one instance a male *Exoglossum* returned to his nest, and took a position facing upstream. He moved slightly to right and left over the nest much as does a male *cornutus*, and several female *cornutus* took a position above and dipped down to take a spawning position beside him. The male *Exoglossum* reacted by turning and rushing at them and finally chased the female shiners away from the nest.

Spawning Act.

With a female above a male and the male alternately inclining himself to a semi-recumbent position first to one side then to the other, conditions are set for the spawning act (Plate I). The female dips downward beside that side of a male which is inclined toward the bottom or making the more acute angle. The anterior end of the head of the female is just beyond the anterior border of the pectoral fin of the male. The pectoral fin of the male is inserted under or slightly behind the head of the female, the distal end of his pectoral being curved upward around the female. At the same time his caudal peduncle is swung up over the caudal peduncle of the female and then the caudal peduncle of the male moves downward. As a result of this pressure the female is lying on her side at right angles to the male with her head toward shore and usually with her ventral side upstream (Plate II).

The male continues to bend his body in such a way as to enclose the female within a curve (Plate III). It appears that the eggs are laid at this moment, the eggs being forced out by the downward pressure exerted by the male. The female then straightens out (Plate IV) and shoots head upwards to, or almost to, the surface just as the male begins to straighten himself. When observing a large group of spawning shiners, females may constantly be seen breaking water as they come out of the spawning embrace. The speed with which this spawning act takes place is a fraction of a second or just slightly longer than the time necessary to snap ones fingers quickly, and the details are about impossible to see clearly with the unaided eye, even when observed at close range. The spawning act is much like that

of *Semotilus atromaculatus atromaculatus* as described by Reighard (1910, p. 1130).

The male shiner immediately takes his position facing upstream and may spawn again with another female in a few seconds. The female swims slowly downstream a few feet, takes a position below the nest and soon comes back to spawn again, at times with the same but usually with a different male. One female was observed to spawn twice with the same male in a period of one minute. A small male about three inches in total length who at the time was the lone male on the nest, was counted spawning 20 times within 10 minutes. There were about 30 females below and over this nest. Although a male will spawn with the female to either side, many more righthanded matings were noted. An exceptionally vigorous male may hold the dominant position in the nest, and spawn many times, for as long as 20 minutes. Most males, however, drop downstream and rest in less than half this time; thus the spawning individuals over a nest are changing constantly.

Male shiners recognize the spawning act when they observe another male spawn. When a breeding group has been purposely frightened away from a nest it is usually one of the smaller male shiners that returns to the nest first, drives away the egg predators and spawns with the first female to come upstream. On the completion of the spawning act from 5 to 10 males would immediately rush to the area and the never-ending battles for the leading places in the nest would resume.

One group of breeding shiners had become conditioned so that when a daily train rushed by at high speed only 20 yards away, spawning continued without interruption. A horned dace that was present in the nest at the same time, however, beat a hasty retreat toward the deep pool above. These shiners were easily frightened by any quick movement such as the passage of a bird close above the water or the movement over the surface of a ripple caused by a sudden gust of wind. However, they did not move when loud vocal notes were made within six feet of them.

A common water snake, *Natrix sipedon sipedon,* approximately two feet in length, once quietly moved downstream into a nest. The snake stopped with its head near the surface and its body dragging on the bottom six inches below. Neither the spawning shiners nor other fishes such as *Rhinichthys a. atratulus* and *Campostoma anomalum pullum* appeared at all disturbed. Several shiners swam leisurely up and casually examined the intruder and one even investigated by touching the snake's body with its mouth as if testing its edibility.

An *Exoglossum* nest that was used by a spawning male shiner was completely covered by the author with large flat stones. The male shiner returned shortly and made a few dashes at adult *Rhinichthys atratulus atratulus* that were eating what eggs they could get in the crevices. The male shiner remained in the immediate vicinity for three minutes and then dropped downstream twenty feet and attempted to drive away another male shiner with a holding over an *Exoglossum* nest.

No exact observations are available but it is thought that but few eggs are laid at one time, probably not more than fifty. Occasionally a very ripe female will lose her entire supply of eggs when she is handled and it is thus probable that at times many more eggs are laid than at others. As has been mentioned above the eggs fall to the bottom and lodge on and among the pebbles of the nest. Apparently few are washed downstream. The flow of water over a depression such as *cornutus* may make, or over the pit of a *Semotilus* nest, is such that eddys are formed, bringing the water in the bottom of the pit to a relatively quiet condition even in fairly fast riffles. Thus very few eggs are washed downstream. When *Exoglossum* and *Nocomis* nests are used the eggs are usually driven into the anterior slope of the nest by the current.

Other species of fishes, chiefly darters and other minnows, are quick to dart in to eat the eggs after a spawning act is consumated. Indeed some *Rhinichthys atratulus atratulus* seem to be conditioned so that they make a mad dash to the spot at the moment spawning occurs. The male shiners are usually successful in keeping these predators at bay.

Although some species of fishes desist from taking food during spawning, both male and female *Notropis cornutus cornutus* will eat during this period. Ball (as reported by Marshall, 1939, p. 153) "found no cessation of feeding during the breeding season" in *Notropis cornutus chrysocephalus*. Ripe females lying in the middle layers of water just below the nest will readily rise to the surface to take insects which are floating by. Males, when not too much occupied with their territory guarding or spawning, will rise to eat these insects.

After the spawning period many of the larger males are found dead. Invariably they are badly fungused. However, most have probably reached the end of the normal life span of the species at this time. Numbers of dead specimens of other species of minnows such as *Campostoma* and *Nocomis* are often seen just after the spawning season is over.

Eggs and Young.

The demersal eggs become adhesive when water-hardened about two minutes after they are laid. At first they are orange but fade considerably in a short time. The average diameter is 1.5 mm. The eggs drop between and are washed under pebbles and some are subsequently buried by the digging activity of the males to a depth of several millimeters in the sand. Some single eggs are found and numbers up to twenty have also been found in loose clumps.

The incubation period is unknown, as every effort to hatch eggs in aquaria resulted in failure. Little definite data is available on the behavior of the newly hatched larvae, but later, after the loss of the yolk sac, the post-larvae may be seen in small schools at and slightly under the surface. At this time they often school with the young of other species as *Catostomus commersonnii commersonnii, Hybognathus regius* and *Notropis hudsonius hudsonius* in the sluggish waters about Ithaca, New York. In smaller streams in the same region the young *cornutus* are to be found in the company of the young of *Rhinichthys atratulus atratulus, Clinostomus elongatus* and *Catostomus commersonnii commersonnii* and other species. After they have reached a length of around 15 mm. they are still to be found in small schools but now they are often seen in fast water as well as in pools.

Throughout the summer the young of the year tend to refrain from associating with juveniles and adults of the same species although by September a few mixed collections of young and small adults have been taken. The schools of juveniles and adults, with but few exceptions, resort to the deeper pools during winter. However, the young are often to be found in great numbers, associated with the young of other species, in shallow, ice covered backwaters along streams. For a detailed description of the eggs and young of *Notropis cornutus chrysocephalus*, the reader is referred to Fish (1932, p. 339).

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Summary.

1. In May an inshore migration in lakes and, in some cases at least, an upstream movement is made by *Notropis cornutus*.

2. Sexual dimorphism is pronounced. Breeding males have well devel-

oped pearl organs or breeding tubercles, are highly colored and reach a larger size than breeding females. The breeding tubercles on the various parts of the body are of value in the fighting which occurs among the males, in driving away predators and in the breeding act.

3. Spawning occurs from May 1 through the middle of July in the northeastern states, beginning usually when the water has reached a temperature of 60° to 65° F. At any one locality spawning lasts about ten days and is limited to the daylight hours.

4. The common shiner may (1) spawn over gravel beds in running water, (2) excavate small depressions in gravel or sand in running water or, (3) utilize the nests built by other species such as *Nocomis micropogon, Nocomis biguttatus, Leucosomus corporalis, Semotilus atromaculatus atromaculatus, Exoglossum maxillingua* and *Campostoma anomalum* whether these are built in running or the still waters of shallow pools. They prefer to spawn over the nests of other species when these are available.

5. Hybridization often occurs with *Notropis cornutus* as one parent largely as a result of their spawning over the nests of other fishes.

6. The number of males that will spawn over one nest varies considerably, there being from one hundred or more over a gravel bed to as few as one male over a small depression. More females are present at the nests than males.

7. Males fight continually for the leading position, the position furthest upstream in the nest.

8. A male shiner recognizes a female and takes a semi-recumbent position alternately from one side to the other when the female approaches from the downstream side of the nest and comes to a position above and slightly downstream from the male.

9. The female reacts to a fish whether it be a male common shiner or another species providing he has taken a position over a nest, head facing upstream and moving slightly from side to side.

10. The female takes the initiative in the breeding act by dipping downward, to lie beside the male. The male throws his caudal peduncle over that of the female, curves his body by bringing his head and tail in close proximity with his pectoral fin underneath the head of the female. The eggs are forced from the female at this moment while she lies, usually on her side, her ventral surface facing upstream and her head pointing toward shore. The entire breeding act is over in a fraction of a second and the details cannot be clearly seen with the unaided eye.

11. Probably fewer than fifty eggs are laid at once. The demersal eggs become adhesive after water-hardening in about two minutes after being laid and drop between the pebbles on the bottom of the nest to which they adhere. When first laid they are orange and average 1.5 mm. in diameter.

Bibliography.

Adams, Charles C. & Hankinson, T. L.

1928. The ecology and economics of Oneida Lake Fish. *Bull. New York State College of Forestry,* Syracuse University, Vol. 1, No. 4a (*Roosevelt Wild Life Annals,* Vol. 1, Nos. 3 and 4): 235-548.

Fish, Marie Poland

1932. Contributions to the early life histories of sixty-two species of fishes from Lake Erie and its tributary waters. *Bull. U. S. Bur. of Fisheries,* Vol. 47: 293-398.

Forbes, Stephen Alfred & Richardson, Robert Earl

1920. The fishes of Illinois. Second Edition. Nat. Hist. Surv. Ill., Vol. 3: pp. 1-cxxxi; 1-357.

FOWLER, H. W.

1909. A synopsis of the Cyprinidae of Pennsylvania. *Proc. Acad. of Nat. Sci. of Phil.* for 1908 (1909): 517-553.

1912. Some features of ornamentation in fresh water fishes. *Am. Naturalist*, Vol. 46: 470-476.

GREELEY, J. R.

1927. Fishes of the Genesee Region with Annotated List. *In*: A Biological Survey of the Genesee River System. *Suppl. 16th Ann. Rept. N. Y. Cons. Dept.*, 1926: 47-66.

1929. Fishes of the Erie-Niagara Watershed. *In*: A Biological Survey of Erie-Niagara System. *Suppl. 18th Ann. Rept. N. Y. Cons. Dept.*, 1928: 150-179.

1931. Fishes of the Area with Annotated List. *In*: A Biological Survey of the St. Lawrence Watershed. *Suppl. 20th Ann. Rept. N. Y. Cons. Dept.*, 1930: 44-94.

1932. Fishes of the Area with Annotated List. *In*: A Biological Survey of the Oswegatchie and Black River Systems. *Suppl. 21st Ann. Rept. N. Y. Cons. Dept.*, 1931: 54-92.

1938. Fishes of the Area with Annotated List. *In*: A Biological Survey of the Allegheny and Chemung Watersheds. *Suppl. 27th Ann. Rept. N. Y. Cons. Dept.*, 1937: 48-73.

GREENE, C. WILLARD

1935. The distribution of Wisconsin fishes. State of Wisconsin, Conservation Commission, Madison: 1-235.

HANKINSON, T. L.

1908. A biological survey of Walnut Lake, Michigan. *Mich. State Board Geol. Surv., Rept. for* 1907 (1908): 157-288.

1920. Report on investigations of the fish of the Galien River, Berrien County, Michigan. *Occ. Papers Univ. of Mich.*, Mus. Zoology, No. 89: 1-14.

1932. Observations on the breeding behavior and habits of fishes in southern Michigan. *Papers Mich. Acad. Sci., Arts and Letters*, Vol. 14, 1931 (1932): 411-425.

HUBBS, CARL L. & COOPER, GERALD P.

1936. Minnows of Michigan. *Bull. of Cranbrook Inst. of Science*, No. 8: 1-95.

KENDALL, W. C. & GOLDSBOROUGH, E. L.

1908. The fishes of the Connecticut Lakes and neighboring waters with notes on the plankton environment. *U. S. Bur. Fisheries*, Doc. 633: 1-77.

MARSHALL, NELSON

1939. Annulus formation in scales of the common shiner, *Notropis cornutus chrysocephalus* (Rafinesque). *Copeia*, (3): 148-154.

NURNBERGER, PATIENCE KIDD

1931. Observations on the spawning temperature of *Luxilus cornutus*. *Trans. Am. Fish. Soc.*, Vol. 61: 215.

REIGHARD, J. E.

1910. Methods of studying the habits of fishes with an account of the breeding habits of the horned dace. *U. S. Bur. Fisheries Bull.*, Vol. 28, for 1908 (1910): 1111-1136.

1915. An ecological reconnaissance of the fishes of Douglas Lake, Cheboygan County, Michigan, in Midsummer. *U. S. Bur. Fisheries Bull.*, Vol. 33: 215-249.

THOMPSON, DAVID H.

1935. Hybridization and racial differentiation among Illinois fishes. Natural Hist. Surv. Ill. in Appendix. Vol. 20: 492-494.

TRACY, H. C.

1910. Annotated list of the fishes known to inhabit the waters of Rhode Island. *Fortieth Ann. Rep. Comm. of Inland Fisheries of Rhode Island*: 35-176.

VAN DUZER, EVELYN M.

1939. Observations on the breeding habits of the cut-lips minnow, *Exoglossum maxillingua*. *Copeia*, (2): 67-75.

EXPLANATION OF THE PLATES.

Plate I.

A typical breeding group of *Notropis cornutus cornutus* over a nest begun by a male *Semotilus atromaculatus atromaculatus* at Willseyville, New York. The large male at the right, occupying the leading position in the nest, is assuming a semi-recumbent position in anticipation of spawning with the small female now dipping toward his left side. He is followed by eight males which are easily recognized by the prominent light colored streak along the upper side. Three small females are to be seen to the left and one is downstream from this group of eight males. Another female appears above the third from the last male in the nest. Several other females, that do not appear in the photograph, were scattered further downstream. All fishes are facing upstream.

Plate II.

The beginning of a spawning act in which a small male *cornutus*, to the right of the larger leading male in the nest, has thrown his body over that of the female who now lies on her side. The breeding male is just starting to bring his caudal peduncle toward the head in the typical breeding curve. The right pectoral fin of the male is under the anterior end of the female. This much of the spawning act had happened so rapidly that the other three males to his left have apparently not noted it. The upstream male will probably turn on the spawning male and drive him off when he finally sees him. The open mouth is typical of a spawning male. Two female *cornutus* are to the left and one is behind the male on the left side of the spawning group. Two males on the downstream side of the nest appear at the extreme left of the figure. Note the adult *Rhinichthys atratulus atratulus* in the right foreground on the periphery of the nest in a search for eggs.

Plate III.

The climax of the breeding act has been reached with the male *cornutus* in the foreground curved over the female. Although the pectoral fin of the male is usually under the female it is above in this case and the position of the female is somewhat abnormal. The eggs are forced out of the female at this point. Another female may be seen above and to the left of the leading male in the nest. The two males near the center of the figure are in a position males assume before attempting to dash at each other. Note that their heads and caudal fins are apart while their bodies almost touch in the middle. The light colored tubercles of the males stand out against the dark background of the skin. Three males may be seen at the extreme left of the figure where the water breaks over the riffle. An adult *Rhinichthys atratulus atratulus* is present in the right foreground.

Plate IV.

The breeding act has been completed. The male *cornutus* is straightening his body and the female has started to move upward. The large dominating male to his right is turning to rush at the male that has just spawned. Three other males are near the middle of the nest and four more appear at the left of the figure. One small female is present just in back of the largest male near the center of the photograph. Two other females appear in the upper right hand corner. An adult *Rhinichthys atratulus atratulus* is present in the foreground.

THE BREEDING BEHAVIOR OF THE COMMON SHINER, NOTROPIS CORNUTUS (MITCHILL).

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